# Gaseous Decomposition Products of Safety Powders

by C. E. Cubbison

*1912*

Submitted to the Department of Chemical Engineering of the University of Kansas in partial fulfillment of the requirements for the Degree of Bachelor of Science

# GASEOUS DECOMPOSITION PRODUCTS OF SAFETY POWDERS

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THESIS SUBMITTED FOR THE DEGREE OF
BACHELOR OF SCIENCE
IN THE
DEPARTMENT OF CHEMICAL ENGINEERING
AT THE
UNIVERSITY OF KANSAS.

BY
C.E.CUBBISON
I912.

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# PREFACE.

It is the object of the Government Testing Station at Pittsburg, Pennsylvania to test explosives under conditions as nearly identical as possible with those encountered in actual mining practice. When an explosive passes the requisite tests it is placed on the permissible list.

Most permissible explosives are probably safe enough to use in coal mines under all ordinary conditions but it seems highly probable that the gases given off from the decomposition of some of the powders when mixed with coal dust and air, or fire damp and air, or both may form an inflamable mixture which could be readily ignited.

The investigation is a continuation of the work of Mr. Victor E. Lednicky carried on at the University last year.

The work was done under the personal direction of Prof C.M.Young, to whom much credit is due for valuable suggestions.

University of Kansas C.E.Cubbison.

Lawrence, Kansas.

May 1912.

# Gaseous Decomposition Products of Safety Powders.

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## Introduction.

Explosives which are to be used in coal mines must possess besides the qualities of strength, efficiency in breaking down coal, and freedom from large quantities of poisonous or offensive explosive products; the property of not readily causing explosions of mixtures of mine gas and air and of coal dust and air, or both.

Permissible explosives give a short and relative cool flame and is therefore less likely to cause an explosion where gases or dust are present than would the use of dynamite or black powder which give a longer and hotter flame. The relative cool flame of permissible explosives is sometimes produced by adding an excess of carbon to the explosive whereby the amount of carbon monoxide is increased and the amount of carbon dioxide is decreased. The lowering of the temperature of the flame is caused by the difference in heat of formation of carbon monoxide and of carbon dioxide. Substances containing water, salts having water of crystallization,

inert materials,and the easily volatile salts are all used to reduce the flame temperature.

General Method Of Conducting Investigation.

A weighed amount of the explosive to be tested was placed in a gas tight steel cylinder with a detonator and match.The charge was fired electrically by means of a blasting machine.The gases were then drawn off from the cylinder,collected and the volume measured.A sample of the gas was then taken and analyzed for carbon dioxide,heavy hydrocarbons,oxygen,carbon monoxide,methane and hydrogen.The residue was called nitrogen.A qualitative test was made for hydrogen sulphide.

## APPARATUS AND METHODS.

### Bomb:

The steel cylinder,see Plate I,called a bomb,in which the charge was fired was turned from machine steel. It measures eight inches long by four inches in diameter. There is a I 3/16 inch hole drilled and tapped in one end to a depth of 2 I/4 inches.Concentric with this is a I inch hole drilled to a depth of 3 I/4 inches.A circular brass washer is mortised in between the base of the threads and the one inch chamber. A tapped plug cut from a two inch bar fits the larger hole. The end of the plug

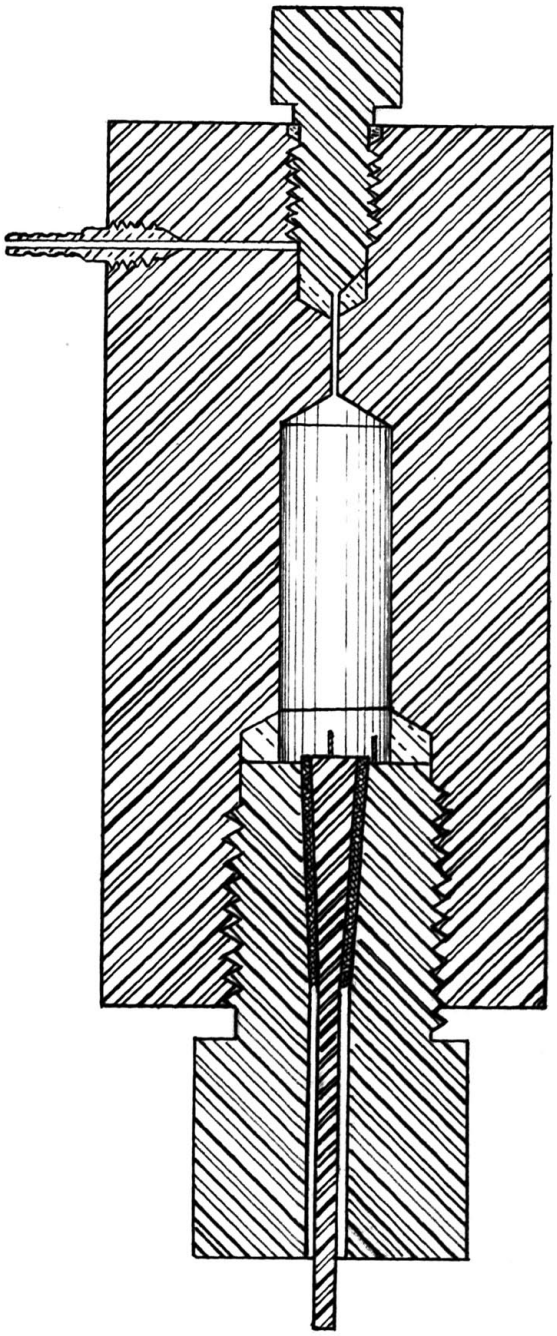

Plate I.- Section through Bomb.

is polished to fit tightly against the brass washer. A I/I6 inch pin,I/4 inch long is set in the end of the plug I/2 inch from the center. One end of the electric match was attached to this. Through the center of the plug is a 5/I6 inch drilled hole. At the face of the plug this hole is enlarged to 5/8 inch and tapers back for two and I/4 inches. A tapered pin fits this opening and extends about I/2 inch out of the plug.The tapering end of the pin was covered with wood fiber about I/8 in. thick. The rest of the tapered pin is ~~three~~ 3/I6 inches in diameter and thus the taper pin is insulated from the plug. There is a I/I6 inch pin 3/8 inch long set in the center of the larger end of the taper pin. To this pin was attached the other end of the electric match,In the other end of the bomb is an II/I6 inch hole,I I/2 inches deep,tapped for I inch beginning I/4 inch from the outside. At the bottom of this hole is a conical shaped washer against which an II/I6 inch conical shaped screw plug fits. A brass washer I/4 inch thick is fitted into the upper part of the hole. Between the base of the threads and the washer at right angles is a 7/I6 inch hole. A screw nipple connects from the side of the bomb with this hole. A small hole connects the I inch hole and the bottom of the conical shaped hole in the other

end of the bomb.

## Charge.

A charge, for finding the decomposition products of powder alone, consisted of five grams of the powder, an electric match, and a detonating cap. The charge was contained in a paper cartridge. The cartridges were prepared by rolling ordinary paper into the form of a cylinder about 3/4 inch in diameter, sealing the side and one end. The electric matches used were obtained from the Star Electric Fuse Works. They were not a finished product but are used by the company in the manufacture of their Red Spitter fuses. The caps used were No.7 Fulminate Detonating Caps, bought of the Independent Powder Co. of Carthage, Mo.

The match was placed in the cap and the top of the cap was then pressed tightly around the wires of t the match. The cap and match were then placed in the cartridge and the powder pressed down around them. The paper of the cartridge was then pressed down over the charge. The wires were the bared and one wire was fastened around the pin extending from the screw plug and the other wire was fastened around the pin in the insulated pin.

The plugs were then screwed firmly into the bomb. One terminal of the blasting machine was connected by means of a wire to the end of the insulated pin which extended out of the plug. The other terminal was connected in a like manner to the screw nipple in the side of the bomb.

## The Gas Measuring Devise.

A I000 ccm. glass bottle graduated to I0 ccm., fitted with a two holed stopper, through one opening of which was passed a glass tube extending to the bottom of the bottle and through the second opening a short piece of glass tubing was passed. Both tubes were closed by means of pieces of rubber tubing and pinch cocks. The bottle, filled with water saturated with the gaseous products of decomposition of powder, was clamped in an inverted position to a standard. After a charge had been fired the longer tube was fastened to the nipple on the bomb by means of a piece of rubber tubing, and the pinch cocks were opened. The conical pointed screw in the bomb was then carefully loosened. The gases on passing into the bottle displaced the water. The rate of flow of the gas could be easily regulated by means of the screw.

When about I000 ccm. had been drawn off the flow of gas was stopped and the bottle replaced by a similar one. The volume could be read directly from the graduations on the bottle.

## Methods of Analysis.

In the analysis a simple gas burette (see fig.I) was used to measure the volume of the gases. This consista of two glass tubes which are set in weighted wooden feet.Inside the feet the tubes are contracted and bent at right angles. The tubes are connected by means of a rubber tube about I00 cm.long.One tube called the measuring tube ends at the top in a capillary tube. A short piece of rubber tubing is wired on this and enclosed by a pinch cock.The measuring tube is graduated into I00 ccm. with 0.2 ccm. divisions;the lowest division being slightly above the wooden base.The other tube called the level tube is a plain glass tube open at the top. The measuring tube was filled with water saturated with gaseous products of powder explosion by pouring the water into the level tube,opening the pinch cock,and raising the level tube until the water displaced the air in the measuring tube then the pinch cock was closed.

The water was poured out of the level tube until it stood just above the wooden base. The measuring tube was then connected by means of a short piece of capillary tube with the longer tube in the bottle which contained the gas to be analyzed. Pinch cocks were opened and water was forced into the bottle.The water forced the gas into the burette. A little over I00 ccm.were run into the burette each time and the pinch cocks were then closed.

To obtain a sample of exactly I00 ccm.the level tube was raised,after allowing the water to run down, until the meniscus stood at the I00 ccm. The rubber tube was then compressed against the base of the base of the burette and the pinch cock was opened for a moment; the excess of gas escaped and exactly I00 ccm.remained in the burette.

## Determination of Carbon Dioxide.

The carbon dioxide was determined by passing the gas into a simple absorption gas pipette,contatning a potassium hydroxide solution and measuring the decrease in volume. The potassium hydroxide solution would absorb besides the carbon dioxide any hydrogen sulphide which was present in the gas;but as all gases were tested for hydro-

gen sulphide which with lead acetate paper and none were found which contained any hydrogen sulphide;Consequently the contraction in the volume of the gas sample taken gave directly the amount of carbon dioxide.

The potassium hydroxide solution was prepared by dissolving one part of commercial caustic potash in two parts of water.

The simple absorption pipette(see figure I) consists of two large bulbs joined by a tube and a capillary tube bent as shown in the figure.

The burette was connected to the pipette by means of a short piece of capillary tubing bent at right angles at both ends and connected by means of short pieces of rubber tubing.

Determination of Heavy Hydrocarbons.

The hydrocarbons higher than methane,sometime called illuminants,were determined by passing the gas residue after the absorption of the carbon dioxide into a pipette containing fuming sulphuric acid;then into a pipette containing potassium hydroxide solution which removed the sulphuric acid vapors which were carried over with the gas and then measuring the decrease in volume.

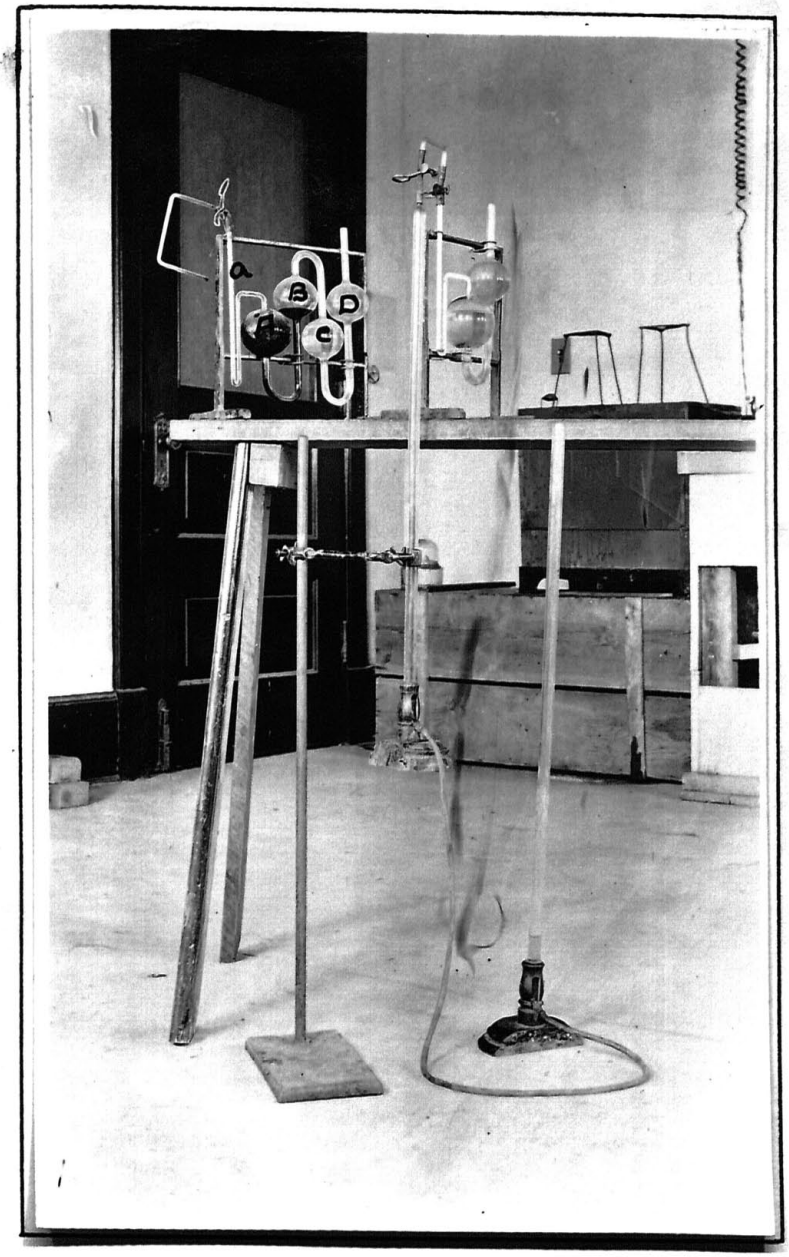


Fig.1— Simple Pipettes and Burette

## Determination of Oxygen.

The amount of oxygen present was determined after the hydrocarbon determination by the contraction noted when the gas was passed into an alkaline pyrogallate solution contained in a double absorption pipette.

The alkaline pyrogallate solution was prepared by mixing together in the pipette five grams of pyrogallol disolved in I5 ccm. of water and I20 grams of potassium hydroxide dissolved in 80 ccm. of water.

The double absorption pipette(see figure I.) consists of a large glass bulb 'A' of about I50 ccm.capacity and three smaller bulbs 'B,C,D'of about I00 ccm. capacity. The bulbs are connected by the bent tube and end in the bent capillary tube 'a' as shown in the figure. The bulb'A'was filled with the pyrogallate solution and'C'with water,which prevents the solution from absorbing the oxygen from the air.

## Determination of Carbon Monoxide.

After the oxygen determination the amount of carbon monoxide present was determined by the amount of gas absorbed by an ammonical cuprous chloride solution.

The solution was contained in double absorption pipettes. Two pipettes were used. The gas was first passed into a pipette containing a solution which had been used frequently and was then passed into a pipette containing a comparatively fresh solution.

Ammonical cuprous chloride solution was prepared by the method given by Lunge and Keane in "Technical Methods of Chemical Analysis". A stock solution was prepared by dissolving 200 grams of cuprous chloride in a solution of 250 grams of ammonium chloride in 750 ccm. of water.The solution was kept in a well stoppered bottle and was prepared for use as required by adding to it one third of its volume of ammonium hydroxide of 0.905 Specific Gravity.

Determination of Hydrogen and Methane.

The amount of hydrogen and methane present were determined by ~~t~~-he combustion with the addition of air in a simple explosion ~~of~~ pipette.

The explosion pipette (see figure 2)consists of a thick walled explosion bulb'A' and a level bulb 'B' which are joined together by a piece of heavy rubber tubing.At 'a' two small platinum wires are fused into the bulb 'A' the ends of wires being about 2 mm.apart.

There is a glass stop cock at the 'b' and the explosion bulb ends in the capillary tube 'c'. Mercury was used as the confining liquid so that the carbon dioxide formed by the explosion might be measured. If the explosion was made over water a considerable amount of the carbon dioxide would be absorbed owing to the high pressure caused by the explosion.

A measured portion of the residue gas from the previous determinations was mixed with a measured volume of air and run into the explosion pipette and the mixture was exploded by connecting the terminals of an induction coil to the two platinum wires in the explosion bulb. The gases were allowed to cool then were run back into the burette and the contraction noted. The gases were then run into a pipette containing potassium hydroxide solution and the amount of carbon dioxide formed was thus measured The gases were then passed into a pipette containing pyrogallate solution and the contraction noted. This was done to make sure that there was an excess of oxygen present. Usually all the oxygen was not absorbed but the gases were allowed to remain in contact with the solution long enough to make sure there was an excess of oxygen.

The contraction is due to the fact that upon explosion the hydrogen of the gas combines with the oxygen

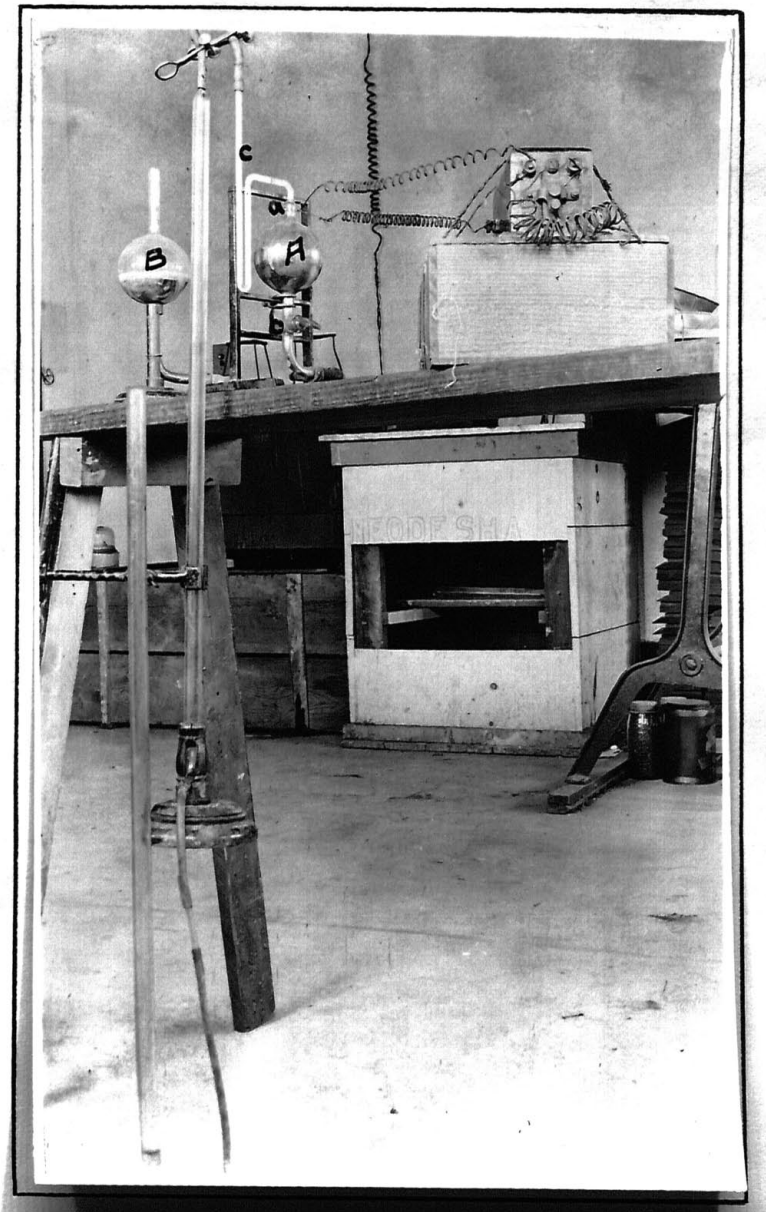


Fig 2 - Explosion Pipette and Induction Coil

of the air and forms water ,while the carbon of the methane combines with the oxygen and foms carbon dioxide. From the equation:

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

it will be seen that the volume of carbon dioxide formed is equal to the amount of methane present.

Therefore the contraction of the gas mixture upon passing it into the potassium hydroxide solution will be equal to the methane present in the portion of gas taken for the explosion.

The contraction due to the carbon dioxide is equal to twice the volume of methane present,because the methane in burning combines with twice its volume of oxygen as is seen from the above equation,and this is caused by the oxygen consumed,or to twice the volume of methane present. The amount of hydrogen present is equal to two-thirds of the total contraction less that due to the methane as can be seeh from the equation:

$$2H_2 + O_2 = 2H_2O.$$

## Determination of Nitrogen.

The undetermined constituents,called nitrogen,were found by subtracting the sum of the volumes of hydrogen

and methane found from the volume of gas residue taken for the explosion.

The gases were allowed to remain in contact with the potassium hydroxide,pyrogallate,and cuprous chloride solutions until no further contraction was noted on passing the gas back into the burette.

Before measuring any volume of gas the burette was allowed to stand three minutes before taking a reading to allow the water to run down the sides of the burette. All gas volumes were read to the nearest tenth ccm.

To correct for the changes in volume of the gas being analyzed caused by the changes in temperature and pressure a second burette was provided.A measured volume of air was contained in this burette and any change noted in this volume during the course of analysis of a gas was applied directly to the gas being analyzed .

## Method of Calculating Results.

The method of calculating results can probably be best shown by means of a typical example.

Let us assume that there were 2500 ccm.of gas given off from the explosion of a certain powder which upon analysis gave the following result:-

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for analysis ------- | 100.0 | |
| Residue after absorption of carbon dioxide -------- | 78.2 | 100.0 - 78.2 = 21.8 |
| Residue after absorption of heavy hydrocarbons ---- | 76.8 | 78.2 -76.8 = 1.4 |
| Residue after absorption of oxygen ---------- | 70.9 | 76.8 - 70.9 = 5.9 |
| Residue after absorption of carbon monoxide ------- | 50.4 | 70.9 - 50.4 = 20.5 |
| Hydrogen and methane by explosion. | | |
| Total residue ---------- | 50.4 | |
| Portion taken ---------- | 15.8 | |
| Volume of air added ----- | 70.6 | |
| Total volume ---------- | 86.4 | |
| Volume after explosion -- | 74.3 | |
| Contraction ---------- | 12.1 | |
| Residue after absorption carbon dioxide ---------- | 71.1 | 74.3 - 71.1 = 3.2 |
| Residue after absorption of oxygen ---------- | 69.9 | 71.1 - 69.9 = 1.2 |

The I5.8 ccm. of gas residue taken formed 3.2 ccm. of carbon dioxide upon explosion;this is equal to the amt. of methane present.The total amt.of methane ~~used~~ is found as follows:

I5.8 : 50.4 :: 3.2 : X.

X = I0.2 ccm.or per cent Methane.

The hydrogen in the I5.8 ccm.is found by the equation:

2/3 ( I2.I - ( 2 x 3.2) ) = 3.8 ccm.of hydrogen.

and the total amount of hydrogen is :-

I5.8 : 50.4 :: 3.8 : X

X = I2.I ccm.or per cent hydrogen.

The nitrogen in the I5.8 ccm.is :-

I5.8 - ( 3.2 - 3.8 ) = 7.7 ccm.

and the total amount of nitrogen is :-

I5.8 : 50.4 :: 7.7 : X.

X = 28.0 ccm. or per cent nitrogen.

But since part of these gases came from the cap and match these results will have to be corrected to get the percentage of each constituent of the gas which came from the decomposition of the powder.It was found when the match and cap were exploded alone they gave 330 ccm.of gas of the following composition:

I3.7 percent Carbon Dioxide.

0.0 per cent Heavy Hydrocarbons.

4.9 per cent Oxygen.

22.0 per cent Carbon monoxide.

0.0.per cent Methane.

0.0 per cent Hydrogen.

59.4 per cent Nitrogen.

To obtain the percentage of each constituent which came from the powder alone we will multiply the total volume of gas obtained by the per cent of this constituent in the gas analyzed and subtract from this the volume of gas given off by the cap and match multiplied by the per cent of the same constituent in the gas from the cap and match and divide the result by the volume of gas which comes from the powder alone.

$$\frac{(2500 \times 21.8) - (330 \times 13.7)}{2500 - 330} = 23.0 \text{ per cent } CO_2$$

$$\frac{(2500 \times 1.4) - (330 \times 0.0)}{2500 - 330} = 1.6 \text{ per cent heavy hydrocarbons.}$$

$$\frac{(2500 \times 5.9) - (330 \times 4.9)}{2500 - 330.} = 5.1 \text{ per cent } O_2.$$

$$\frac{(2500 \times 20.5) - (330 \times 22.0)}{2500 - 330.} = 20.7 \text{ per cent CO.}$$

$$\frac{(2500 \times 10.2) - (330 \times 0.0)}{2500 - 330} = 11.3 \text{ per cent } CH_4.$$

$$\frac{(2500 \times 12.1) - (330 \times 0.0)}{2500 - 330} = 13.9 \text{ per cent } H_2$$

$$\frac{(2500 \times 28.0) - (330 \times 59.4)}{2500 - 330} = 23.2 \text{ per cent } N_2.$$

| Gases | As Analyzed Per cent | Corrected Percent |
|---|---|---|
| $CO_2$--------- | 21.8 | 23.0 |
| Heavy hydrocarbons----- | 1.4 | 1.6 |
| $O_2$--------- | 5.9 | 5.1 |
| $CH_4$--------- | 10.2 | 11.3 |
| $H_2$---------- | 12.1 | 13.9 |
| $N_2$---------- | 28.0 | 23.2 |
| CO--------- | 20.5 | 20.7 |
| Total------- | 99.9 | 99.8 |
| Combustible- | 44.2 | 47.5 |

The heavy hydrocarbons, carbon monoxide, hydrogen, and methane are taken as the combustible constituents.

Cap and Match.

Residue, dry, fine, and powdery, containing mercury.

Total volume of gas, 330 ccm.

Character of gas, burned with clear blue flame; did not blacken lead acetate paper.

| | Burette reading ccm. | Per cent. | |
|---|---|---|---|
| Amount of gas mixture taken for analysis ------- | 100.0 | | |
| Residue after absorption of carbon dioxide -------- | 86.3 | 100.0 - 86.3 | 13.7 |
| Residue after absorption of heavy hydrocarbons ---- | 86.3 | 86.3 - 86.3 | 0.0 |
| Residue after absorption of oxygen ---------- | 81.4 | 86.3 - 81.4 | 4.9 |
| Residue after absorption of carbon monoxide ------- | 59.4 | 81.4 - 59.4 | 22.0 |
| Hydrogen and methane by explosion. | | | |
| Tptal residue ---------- | 59.4 | | |
| Portion taken ---------- | 29.0 | | |
| Volume of air added ------ | 176.8 | | |
| Total volume ---------- | 205.8 | No explosion. | |

The gas from the cap and match therefore has the following composition:-

| | | |
|---|---|---|
| $CO_2$ | ------- | I3.7 per cent. |
| Heavy hydrocarbons | | 0.0 per cent. |
| $O_2$ | -------- | 4.9 " " |
| CO | -------- | 22.0 " " |
| $CH_4$ | -------- | 0.0 " " |
| $H_2$ | ---------- | 0.0 " " |
| $N_2$ | -------- | 59.4 " " |
| Total | -------- | I00.0 " " |
| Combustible | | 22.0 "" " |

The cap and match were used with all the powders therefore the results obtained from the analysis will have to be corrected to obtain the true percentage of each constituent which came from the powders.

## Sinnamahoning Collier No.4.

Explosive, Sinnamahoning Collier NO.4.

Manufactured by the Keystone National Powder Co.
Emporium, Penn.

Color of explosive: dirty yellowish.

Consistency: dry, Non-cohesive.

Charge: 5 grams.

Residue: hard, dry, coke-like having a strong odor of ammonia.

Total volume of gas: 2480 ccm.

Character of gas: burned with clear blue flame, did not blacken lead acetate paper.

(Sample of powder over one year old.)

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for analysis-------- | 100.0 | |
| Residue after absorption of carbon dioxide -------- | 92.8 | 100.0-92.8=7.2 |
| Residue after absorption of heavy hydrocarbons ---- | 92.8 | 92.8 - 92.8= .0. |
| Residue after absorption of oxygen ---------- | 84.8 | 92.8-84.8=8.0 |

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Residue after absorption of carbon monoxide ----- | 62.0 | 84.8 - 62.0 = 22.8 |
| Hydrogen and methane by explosion. | | |
| Total residue ---------- | 62.0 | |
| Portion taken ---------- | I8.0 | |
| Volume of air added ---- | 86.5 | |
| Total volume ---------- | I04.5 | |
| Volume after explosion-- | 85.0 | |
| Contraction ---------- | I9.5 | |
| Residue after absorption of carbon dioxide ------ | 79.6 | 85.0 - 79.6 = 5.4 |
| Oxygen present --------- | | Excess. |

Sinnamahoning Collier No.4.

| Gases. | As analyzed per cent. | Corrected per cent. |
|---|---|---|
| $CO_2$ ---------- | 7.2 | 5.5 |
| Heavy hydrocarbons | 0.0 | 0.0 |
| $O_2$ ---------- | 8.0 | 8.5 |
| CO ---------- | 22.8 | 22.9 |

| Gases | As analyzed per cent. | Corrected, per cent. |
|---|---|---|
| $CH_4$ ---------- | I8.6 | 2I.4 |
| $H_2$ ---------- | I9.9 | 22.9 |
| $N_2$ ---------- | 23.4 | I8.8 |
| Total ---------- | 99.9 | I00.I |
| Combustible ------ | 6I.3 | 67.2 |

## Tunnelite No.5.

Explosive, Tunnelite No.5.

Class, Nitroglycerine.

Manufactured by the G.R.Mc Abee Powder and Oil Co.
Pittsburg,Pa.

Color of explosive: Yellowish,containing a green salt.

Consistency: Damp,slightly cohesive.

Charge: 5 grams.

Residue: Black,friable,smelling of ammonia.

Total volume of gas: 3100 ccm.

Character of gas: Burned with blue flame,did not blacken lead acetate paper.

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for analysis------- | 100.0 | |
| Residue after absorption of carbon dioxide ------- | 77.4 | 100.0 - 77.4 = 22.6. |
| Residue after absorption of heavy hydrocarbons --- | 77.4 | 77.4 - 77.4 = 0.0. |
| Residue after absorption of oxygen ---------- | 76.9 | 77.4 - 76.9 = 0.5. |

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Residue after absorption of carbon monoxide ------ | 56.4 | 76.2 - 56.4 = 20.5. |
| Hydrogen and methane by explosion ---------- | | |
| Total residue ---------- | 56.4 | |
| Portion taken ---------- | 23.8 | |
| Volume of air added ----- | 75.6 | |
| Total volume ---------- | 99.4 | |
| Volume after explosion -- | 76.2 | |
| Contraction ---------- | 23.2 | |
| Residue after absorption of carbon dioxide ------- | 68.8 | 76.2 - 68.8 = 7.4 |
| Oxygen present---------- | | Excess. |

Tunnelite No. 5.

| Gases | As analyzed per cent | Corrected per cent. |
|---|---|---|
| $CO_2$ | 22.6 | 23.7 |
| Heavy hydrocarbons | 0.0 | 0.0 |
| $O_2$ | 0.5 | 0.0 |
| CO | 20.5 | 20.3 |
| $CH_4$ | I7.5 | I9.7 |
| $H_2$ | I3.2 | I4.7 |
| $N_2$ | 25.6 | 2I.2 |
| Total | 99.9 | 99.6 |
| Combustible | 5I.2 | 54.7 |

## Tunnelite No. 6.

Explosive, Tunnelite No. 6.

Class, Nitroglycerine.

Manufactured by the G. R. McAbee Powder and Oil Co., Pittsburg , Penn.

Color: Similar to Tunnelite No.8 ,butcontaining more of the green salt.

Consistency: About the same as Tunnelite No. 8.

Charge: 5 grams.

Residue: Black, hard, dry.

Total volume of gas: 3340 ccm.

Character ofg gas: Burned with clear blue flame, did not blacken lead acetate paper.

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for analysis ------ | 100.0 | |
| Residue after absorption of carbondioxide --------- | 82.2 | 100.0 - 82.2 = 17.8 |
| Residue after absorption of heavyhydrocarbons ----- | 82.2 | 82.2 - 82.2 = 0.0 |

| | Burette reading ccm. | Per cent |
|---|---|---|
| Residue after absorption of oxygen ---------- | 77.8 | 82.2 - 77.8 = 4.4 |
| Residue after absorption of carbon monoxide ------- | 59.2 | 77.8 - 59.2 = I6.6 |
| Hydrogen and methane by explosion ---------- | | |
| Total residue ---------- | 59.2 | |
| Portion taken ---------- | 23.8 | |
| Volume of air added ------ | 56.7 | |
| Total volume - ---------- | 80.5 | |
| Volume after explosion --- | 65.9 | |
| Contraction ---------- | I4.5 | |
| Residue after absorption of carbon dioxide -------- | 60.5 | 65.9 - 60.5 = 5.4 |
| Oxygen present ---------- | | Excess. |

Tunnelite No.6.

| Gases. | As analyzed per cent. | Corrected per cent. |
|---|---|---|
| $CO_2$---------- | I7.8 | I8.2 |
| Heavy hydrocarbons | 0.0 | 0.0 |
| O2---------- | 4.4 | 4.3 |
| CO ---------- | I6.6 | I6.0 |
| $CH_4$ ---------- | I3.4 | I4.9 |
| $H_2$ ---------- | 6.2 | 6.9 |
| $N_2$ ---------- | 4I.7 | 39.7 |
| Total ---------- | I00.I | I00.0 |
| Combustible ---- | 36.2 | 37.8 |

## Tunnelite No.7.

Explosive, Tunnelite No.7.

Class, Nitroglycerin.

Manufactured by the G.R.McAbee Powder and Oil Co.
Pittsburg,Pa.

Color, Similar to Tunnelite No.6,but the green salt is not so noticeable.

Charge, 5 grams.

Residue, Black,friable with oder of ammonia.

Total volume of gas 2750 ccm.

Character of gas, Burned with clear blue flame.Did not blacken lead acetate paper.

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for analysis-------- | 100.0 | |
| Residue after absorption of carbon dioxide -------- | 81.8 | 100.0 - 81.8 = 18.2. |
| Residue after absorption of heavy hydrocarbons ---- | 81.8 | 81.8 - 81.8 = 0.0. |
| Residue after absorption of oxygen ---------- | 79.2 | 81.8 - 79 2 = 2.6. |

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Residue after absorption of carbon monoxide ------ | 64.7 | 79.2 664.7 = I4.5. |
| Hydrogen and methane by explosion ---------- | | |
| Total residue ---------- | 64.7 | |
| Portion taken ---------- | 27.8 | |
| Volume of air added------ | 80.8 | |
| Total volume ---------- | I08.6 | |
| Volume after explosion--- | 82.6 | |
| Contraction ---------- | 26.0 | |
| Residue after absorption of carbon dioxide ------- | 72.7 | 82.6 72.7 = 9.9. |
| Oxygen present ---------- | | Excess. |

Tunnelite No.7.

| Gases | As analyzed per cent. | Corrected. per cent. |
|---|---|---|
| $CO_2$---------- | 18.2 | 18.9. |
| Heavy hydrocarbons | 0.0 | 0.0. |
| $O_2$---------- | 2.6 | 2.2. |
| CO -------- ------ | 14.6 | 13.6. |
| $CH_4$---------- | 23.0 | 26.1. |
| $H_2$---------- | 9.5 | 10.8. |
| $N_2$------- -------- | 32.1 | 28.3. |
| Total -------- ---- | 100.0 | 99.9. |
| Combustible ------ | 47.1 | 50.5. |

## Tunnelite No.8.

Explosive, Tunnelite No.8.

Class, Nitroglycerin.

Manufactured by the G.R.McAbee Powder and Oil Co.
Pittsburg,Pa.

Color, Yellowish with green particles.

Consistency, Damp and slightly cohesive.

Charge, 5 grams.

Residue, Hard,dry,blackish with odor of ammonia.

Total volume of gas, 3130 ccm.

Character of gas, Burned with clear blue flame;did not bl
blacken lead acetate paper.

| | Burette reading ccm. | Per cent. | |
|---|---|---|---|
| Amount of gas mixture taken for analysis-------- | 100.0 | | |
| Residue after absorption of carbon dioxide ---------- | 73.6 | 100.0 | 73.6 = 26.4. |
| Residue after absorption of heavy hydrocarbons -------- | 73.6 | 73.6 | 73.6 = 0.0. |
| Residue after absorption of oxygen ---------- | 71.3 | 73.6 | 71.3 = 2.3. |

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Residue after absorption of carbon monoxide------- | 49.4 | 7I.3 49.4 = 2I.9 |
| Hydrogen and methane by explosion. | | |
| Total residue ---------- | 49.4 | |
| Portion taken ---------- | I9.6 | |
| Volume of air added ----- | 70.8 | |
| Total volume ---------- | 90.4 | |
| Volume after explosion -- | 74.4 | |
| Contraction ---------- | I6.0 | |
| Residue after absorption of carbon dioxide ------- | 68.8 | 74.4 68.8 = 5.6. |
| Oxygen present ---------- | | Excess. |

Tunnelite No.8.

| Gases | As analyzed per cent. | Corrected per cent. |
|---|---|---|
| $CO_2$ | 26.4 | 27.9 |
| Heavy hydrocarbons | 0.0 | 0.0 |
| $O_2$ | 2.3 | I.9 |
| CO | 2I.9 | 2I.9 |
| $CH_4$ | I4.8 | I6.5 |
| $H_2$ | 8.4 | 9.4 |
| $N_2$ | 26.0 | 22.I |
| Total | 99.8 | 99.7 |
| Combustible | 45.I | 47.8 |

## Eureka No. 2 L. F.

Explosive, Eureka No. 2 L. F.

Class, nitroglycerine.

Manufactured by the G. R. McAbee Powder and Oil Co.
Pittsburg, Penn.

Color, greenish yellow.

Consistency, damp, fairly cohesive; coarsely ground.

Charge, 5grams.

Residue, whitish, friable; smelling of ammonia.

Total volume of gas, 2900 ccm.

Character of gas, burned with clear blue flame; did not blacken lead acetate paper.

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for analysis | 100.0 | |
| Residue after absorption of carbon dioxide | 75.8 | 100.0 - 75.8 = 24.2 |
| Residue after absorption of heavy hydrocarbons | 75.8 | 75.8 - 75.8 = 0.0 |
| Residue after absorption of oxygen | 75.4 | 75.8 - 75.4 = 0.4 |

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Residue after absorption of carbon monoxide ---------- | 49.2 | 75.4 - 49.2 = 26.2 |
| Hydrogen and methane by explosion | | |
| Total residue ---------- | 49.2 | |
| Portion taken ---------- | 23.5 | |
| Volume of air added ------- | 66.5 | |
| Total volume ---------- | 90.0 | |
| Volume after explosion ---- | 67.8 | |
| Contraction ---------- | 22.2 | |
| Residue after absorption of carbon dioxide --------- | 65.2 | 67.8 - 65.2 = 2.6 |
| Oxygen present ---------- | | Excess. |

Eureka No. 2 L. F.

| Gases | As analyzed per cent | Corrected per cent. |
|---|---|---|
| $CO_2$ ---------- | 24.2 | 25.5 |
| Heavy hydrocarbons | 0.0 | 0.0 |
| $O_2$ ---------- | 0.4 | 0.0 |
| CO ---------- | 26.2 | 26.7 |
| $CH_4$---------- | 5.5 | 6.I |
| $H_2$ ---------- | 20.0 | 26.6 |
| $N_2$ ---------- | 23.6 | I4.9 |
| Total ---------- | 99.9 | 99.8 |
| Combustible ------ | 5I.7 | 59.4 |

## Tunnelite No. 8 L. F.

Explosive, Tunnelite No. 8 L.F.

Class, nitroglycerin.

Manufactured by the G. R. McAbee Powder and Oil CO.
Pittsburg , Penn.

Color, yellowish green.

Consistency, dry; not very cohesive; coarsely ground.

Charge, 5 grams.

Residue, greyish, friable; smelling of ammonia.

Total volume of gas, 3550 ccm.

Character of gas, burned with blue flame; did not blacken lead acetate paper.

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for anglysis --------- | 100.0 | |
| Residue after absorption of carbon dioxide ---------- | 75.2 | 100.0 - 75.2 = 24.8 |
| Residue after absorption of heavy hydrocarbons -------- | 75.0 | 75.2 - 75.0 = 0.2 |

| | Burette reading ccm. | Percent. |
|---|---|---|
| Residue after absorption of oxygen ---------- | 75.0 | 75.0 - 75.0 = 0.0 |
| Residue after absorption of carbon monoxide ---------- | 47.8 | 75.0 - 47.8 = 27.2 |
| Hydrogen and methane by explosion | | |
| Total residue ---------- | 47.8 | |
| Portion taken ---------- | 12.4 | |
| Volume of air added ------- | 64.8 | |
| Total volume ---------- | 87.2 | |
| Contraction ---------- | 13.5 | |
| Residue after absorption of carbon dioxide ---------- | 71.0 | 73.7 -71.0 = 2.7 |
| Oxygen present ---------- | | Excess. |

Tunnelite No. 8 L.F.

| Gases | As analyzed per cent | Corrected per cent. |
|---|---|---|
| $CO_2$ ---------- | 24.8 | 25.9 |
| Heavy hydrocarbons | 0.2 | 0.2 |
| $O_2$ ---------- | 0.0 | 0.0 |
| CO ---------- | 27.2 | 27.7 |
| $CH_4$ ---------- | 10.3 | 11.3 |
| $H_2$ ---------- | 20.8 | 22.9 |
| $N_2$ ---------- | 16.6 | 12.2 |
| Total ---------- | 99.9 | 100.2 |
| Combustible ------ | 58.5 | 62.1 |

## Tunnelite No. 6 L.F.

Explosive, Tunnelite No.6 L.F.

Class, nitroglycerin.

Manufactured by the G.R. McAbee Powder and Oil Co.

Pittsburg, Penn.

Color, light yellow.

Consistency, dry, slightly cohesive.

Charge, 5 grams.

Residue, dry, black, friable; smelling of ammonia.

Total volume of gas, 3300 ccm.

Character of gas, burned with blue flame; did not blacken lead acetate paper.

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for anglysis -------- | 100.0 | |
| Residue after absorption of carbon dioxide ---------- | 80.0 | 100.0 - 80.0 = 20.0 |
| Residue after absorption of heavy hydro-carbons ------- | 79.6 | 80.0 - 79.6 = 0.4 |

| | BUrette reading ccm. | Per cent. |
|---|---|---|
| Residue after absorption of oxygen ---------- | 79.6 | 79.6 - 79.6 = 0.0 |
| Residue after absorption of carbon monoxide ---------- | 53.4 | 79.6 - 53.4 = 26.2 |
| Hydrogen and methane by explosion | | |
| Total residue ---------- | 53.4 | |
| Portion taken ---------- | Io.I | |
| Volume of air added ------- | 79.8 | |
| Total volume ---------- | 89.9 | |
| Volume after explosion ---- | 80.3 | |
| Contraction ---------- | 9.6 | |
| Residue after absorption of carbon dioxide ---------- | 77.9 | 80.3 - 77.9 = 2.4 |
| Oxygen present ---------- | | Excess. |

Tunnelite No. 6 L.F.

| Gases | As analyzed per cent. | Corrected per cent. |
|---|---|---|
| $CO_2$ | 20.0 | 20.7 |
| Heavy hydrocarbons | 0.4 | 0.4 |
| $O_2$ | 0.0 | 0.0 |
| CO | 26.2 | 26.7 |
| $CH_4$ | I3.9 | I5.3 |
| $H_2$ | I5.3 | I7.0 |
| $N_2$ | 24.3 | 20.0 |
| Total | I00.I, | I00.I |
| Combustible | 55.8 | 59.4 |

## Aetna " A " Coal Powder.

Explosive, Aetna "A" Coal Powder.

Class, nitroglycerin.

Manufactured by the Aetna Powder Co.,Chicago,Ill.

Color, yellowish.

Consistency, dry, non-cohesive.

Charge, 5grams.

Residue, black, coke-like; smelling of ammonia.

Total volume of g as, 3700 ccm.

Character of gas, burned with blue flame, did not blacken lead acetate paper.

(The sample of powder used was over oney- year old)

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for analysis -------- | 100.0 | |
| Residue after absorption of carbon dioxide ---------- | 72.8 | 100.0 - 72.8 = 27.2 |
| Residue after absorption of heavy hydrocarbons -------- | 72.8 | 72.8 - 72.8 = 0.0 |

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Residue after absorption of oxygen ---------- | 72.6 | 72.8 – 72.6 = 0.2 |
| Residue after absorption of carbon monoxide ----- | 47.3 | 72.6 – 47.3 = 25.3 |
| Hydrogen and methane by explosion. | | |
| Total residue ---------- | 47.3 | |
| Portion taken ---------- | II.6 | |
| Volume of air added ---- | 6I.2 | |
| Total volume ---------- | 72.8 | |
| Volume after explosion - | 6I.0 | |
| Contraction ---------- | II.8 | |
| Residue after absorption of carbon dioxide ------ | 59.2 | 6I.0 – 59.2 = I.8 |
| Oxygen present -------- | | Excess. |

Aetna "A" Coal Powder.

| Gases | As analyzed per cent. | Corrected per cent. |
|---|---|---|
| $CO_2$ | 27.2 | 28.5 |
| Heavy hydrocarbons | 0.0 | 0.0 |
| $O_2$ | 0.2 | 0.0 |
| CO | 25.3 | 25.3 |
| $CH_4$ | 7.3 | 8.3 |
| $H_2$ | 22.4 | 24.5 |
| $N_2$ | I7.5 | I3.4 |
| Total | 99.9 | I00.0 |
| Combustible | 55.0 | 58.I |

## Aetna "C" Coal Powder.

Explosive, Aetna "C" Coal Powder.

Class, nitroglycerin.

Manufactured by the Aetna Powder Co., Chicago, Ill.

Color, similar to Aetna "A" but somewhat darker.

Consistency, dry and non-cohesive.

Charge, 5 grams.

Residue, dry, black, coke-like; smelling strongly of ammonia.

Total volume of gas, 3200 ccm.

Character of gas, burned with blue flame; did not blacken lead acetate paper.

(The sample of powder used was over one year old.)

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for analysis ------- | 100.0 | |
| Residue after absorption of carbon dioxide -------- | 75.6 | 100.0 − 75.6 = 24.4 |
| Residue after absorption of heavy hydro-carbons --- | 75.6 | 75.6 − 75.6 = 0.0 |
| Residue after absorption of oxygen ---------- | 75.0 | 75.6 − 75.0 = 0.6 |

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Residue after absorption of carbon monoxide ------- | 58.0 | 75.0 — 58.0 = 17.0 |
| Hydrogen and methane by explosion. | | |
| Total residue ---------- | 58.0 | |
| Portion taken ---------- | 11.1 | |
| Volume added (air)-------- | 67.1 | |
| Total volume ---------- | 78.2 | |
| Volume after explosion --- | 68.0 | |
| Contraction ---------- | 10.2 | |
| Residue after absorption of carbon dioxide -------- | 64.4 | 68.0 — 64.4 = 3.6 |
| Oxygen present ---------- | | Excess. |

## Aetna "C" Coal Powder.

| Gases | As analyzed per cent. | Corrected per cent. |
|---|---|---|
| $CO_2$ | 24.4 | 25.6 |
| Heavy hydro-carbons- | 0.0 | 0.0 |
| $O_2$ | 0.6 | 0.I |
| CO | I7.0 | I6.4 |
| $CH_4$ | I8.8 | 20.9 |
| $H_2$ | I0.4 | II.6 |
| $N_2$ | 28.8 | 25.3 |
| Total | I00.0 | 99.9 |
| Combustible | 46.2 | 48.9 |

## Mixture of Coal Dust and Powder.

Charge, Aetna "A" Coal Powder; 4 grams.

Lansing Coal Dust; I gram.

Residue, dry, black, soot-like.

Total volume of gas, 3450 ccm.

Character of gas, burned with blue flame; did not blacken lead acetate paper.

(Coal dust contained about 38 per cent volatile combustible matter.)

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for analysis ------- | I00.0 | |
| Residue after absorption of carbon dioxide -------- | 83.2 | I00.0 − 83.2 = I6.8 |
| Residue after absorption of heavy hydrocarbons ---- | 83.2 | 83.2 − 83.2 = 0.0 |
| Residue after absorption of oxygen ---------- | 82.8 | 83.2 − 82.8 = 0.4 |
| Residue after absorption of carbon monoxide ------- | 55.I | 82.8 − 55.I = 27.7 |

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Hydrogen and methane by explosion. | | |
| Total residue ---------- | 55.I | |
| Portion taken ---------- | I2.9 | |
| Volume of air added -- -- | 77.I | |
| Total volume ---------- | 90.0 | |
| Volume after explosion -- | 76.7 | |
| Contraction ---------- | I3.3 | |
| Residue after absorption of carbon dioxide ------- | 72.6 | 76.7 – 72.6 = 4.I |
| Oxygen present ---------- | | Excess. |

Mixture of Aetna "A" Coal Powder and Coal Dust.

| Gases. | Aetna"A"and Coal Dust | | Aetna"A". |
|---|---|---|---|
| | as analyzed per cent. | Corrected per cent. | Corrected per cent. |
| $CO_2$ ---------- | I6.8 | I7.I | 28.5 |
| Heavy hydrocarbons | 0.0 | 0.0 | 0.0 |
| $O_2$ ---------- | 0.4 | 0.0 | 0.0 |
| CO ---------- | 27.7 | 28.3 | 25.3 |
| $CH_4$ ---------- | II.5 | I9.4 | 8.3 |
| $H_2$ ---------- | I7.5 | I2.8 | 24.5 |
| $N_2$ ---------- --- | 26.0 | 22.I | I3.4 |
| Total ---------- | 99.9 | 99.7 | I00.0 |
| Combustible ------ | 56.7 | 60.5 | 58.I |

Charge, Aetna "C" Coal Powder; 4 grams.

Lansing,Kansas Coal Dust;I gram.

Residue,dark,black,soot-like.

Total volume of gas, 2900 ccm.

Character of gas,burned with blue flame.

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Amount of gas mixture taken for analysis ------- | I00.0 | |
| Residue after absorption of carbob dioxide -------- | 80.2 | I00.0 — 80.2 = I9.8 |
| Residue after absorption of heavy hydrocarbons ---- | 80.2 | 80.2 — 80.2 = 0.0 |
| Residue after absorption of oxygen ---------- | 80.0 | 80.2 — 80.0 = 0.2 |
| Residue after absorption of carbon monoxide ------- | 59.8 | 80.2 — 59.8 = 20.2 |
| Hydrogen and methane by explosion ----------. | | |
| Total residue ---------- | 59.8 | |
| Portion taken ---------- | II.0 | |
| Volume of air added ------ | 75.I | |
| Total volume ---------- | 86.I | |
| Volume after explosion --- | 75.8 | |

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Contraction ---------- | II0.3 | |
| Residue after absorption of carbon dioxide ------- | 72.6 | 75.8 - 72.6 = 3.2 |
| Oxygen present --------- | | Excess. |

Mixture of Aetna"C"Coal Powder and Coal Dust.

| Gases | Aetna"C" and Coal Dust | | Aetna"C". |
|---|---|---|---|
| | As analyzed per cent | Corrected percent. | Corrected per cent. |
| $CO_2$ ---------- | I9.8 | 20.6 | 25.6 |
| Heavy hyrdrocarbons | 0.0 | 0.0 | 0.0 |
| $O_2$---------- | 0.2 | 0.0 | 0.I |
| CO ---------- | 20.2 | I9.7 | I6.4 |
| $CH_4$ ---------- | I7.4 | I9.6 | 20.9 |
| $H_2$ ---------- | I4.I | I5.9 | II.6 |
| $N_2$ ---------- | 28.2 | 24.I | 25.3 |
| Total ---------- | 99.9 | 99.9 | 99.9 |
| Combustible ------- | 5I.7 | 55.2 | 48.9 |

Charge, Tunnelite No.5; 4 grams

Lansing, Kans. Coal Dust; I gram.

Residue, dry, black, soot-like.

Total volume of gas, 2925 ccm.
Character of gas, burned with blue flame.

| | Burette reading ccm. | Percent. |
|---|---|---|
| Amount of gas mixture taken for analysis -------- | I00.0 | |
| Residue after absorption of Carbon dioxide ---------- | 7I.4 | I00.0 - 7I.4 = 28.6 |
| Residue after absorption of heavy hydrocarbons -------- | 7I.4 | 7I.4 - 7I.4 = 0.0 |
| Residue after absorption of oxygen ---------- | 7I.2 | 7I.4 - 7I.2 = 0.2 |
| Residue after absorption of carbon monoxide ---------- | 5I.0 | 7I.2 - 5I.0 = 20.4 |
| Hydrogen and methane by explosion. | | |
| Total residue ---------- | 5I.0 | |
| Portion taken ----------0- | I0.6 | |
| Volume of air added ------- | 80.0 | |
| Volume after explosion ---- | 76.2 | |
| Contraction ---------- | I4.4 | |

| | Burette reading ccm. | Per cent. |
|---|---|---|
| Residue after absorption of carbon dioxide ---------- | 73.I | 76.2 - 73.I = 3.I |
| Oxygen present ---------- | | Excess. |

Mixture of Tunnelite No. 5 and Coal Dust.

| Gases | Tunnelite No.5 and Coal dust | | Tunnelite No. 5. |
|---|---|---|---|
| | As analyzed per cent | Corrected per cent | Corrected per cent. |
| $CO_2$ ---------- | 28.6 | 30.5 | 23.7 |
| Heavy hydrocarbons | 0.0 | 0.0 | 0.0 |
| $O_2$ ---------- | 0.2 | 0.0 | 0.0 |
| CO ---------- | 20.4 | 20.I | 20.3 |
| $CH_4$ ---------- | I4.9 | I6.7 | I9.7 |
| $H_2$ ---------- | 26.4 | 29.7 | I4.7 |
| $N_2$ ---------- | 9.6 | 3.2 | 2I.2 |
| Total ---------- | I00.I | I00.2 | 99.6 |
| Combustible ------ | 6I.7 | 66.5 | 54.7 |

## Conclusions.

The odor of ammonia noticeable in the residue from the nitroglycerin explosives is,without a doubt,due to the ammonia formed by the combination of nitrogen and hydrogen under the great pressure and the high temperature produced by the explosion.

The results of the analyses would seem to indicate that most (all of those tested) safety powders produce a gas withaa high percentage of combustible constituents when fired alone and that this percentage is increased when they are fired in the presence of coal dust.Undoubtedly when the powder is fired in the presence of coal dust part of the combustible gases comes from the volatile matter of the coal.This would point out the impracticableness of powders which give a large percent of combustible gases being used in mining coal which contains a large per cent of volatile combustible matter.

It is known that inflammable gas mixtures may be ignited by any incandescent substance whose temperature is equal to,or exceeds the ignition temperature,providing the surface of the substance be large enough and the contact with the gas mixture last long enough.Fire damp will ignite at a temperature between 600° and 700° C.

In the presence of coal dust,air,and the powder gases the ignition temperature is undoubtedly lowered,so that it would be possible to easily ignite the mixture,especially after several shots had been fired.If the shots were fired electrically a break in the circuit and the resulting spark,a naked flame or any incandescent substance might ignite the mixture.

Since permissible explosives rely for their safety upon their short, relative cool flame,anything which would increase the duration of the flame would increase the danger attending their use,The quantity of explosive used and the rate of detonation are known to influence the flame. With an explosive,whose rate of detonation is highthe gas mixture may not have time to recede and be struck by the flame,this might be for only a short timebut might be sufficient to cause an explosion.At any rate it would appear that greater safety would be secured by using a powder which gives a low percentage of combustible constituents and has a slow rate of detonation.